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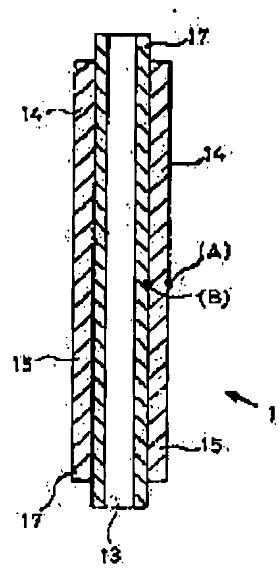
(54) HEAT EXCHANGING METALLIC PIPE AND ADSORPTION TYPE HEAT PUMP

(57)Abstract:
PURPOSE: To provide an adsorption type heat pump capable of performing an adsorption and desorption of adsorptive material in an adsorptive tower within a short period of time.
CONSTITUTION: A heat exchanging metallic pipe 11 has a central hole 13 where heat exchanging fluid can flow through it and a fixed layer 15 in which an adsorptive material 14 is fixed to an outer circumferential surface. The fixed layer 15 is formed by crushing silicagel acting as adsorptive material 14 into 42 meshes, mixing them with binder of vinyl acetate, adhering the mixed material to an outer circumferential surface of a copper tube 17 and sintering it at 110° C for 6 hours. A plurality of heat exchanging metallic pipes 11 are arranged at an adsorptive tower of an adsorptive type heat pump in such a manner that a space where water acting as working fluid can flow is left there, thereby after there occurs a temperature variation through adsorption or desorption of the adsorptive material, a heat exchanging operation is efficiently carried out, the working fluid is uniformly dispersed within the adsorptive tower and no substantial deflection may occur in a distribution of an amount of adsorption. With such an arrangement as above, as compared with the prior art adsorptive type heat pump, a time required for one cycle is shortened.



CLAIMS

[Claim(s)]
[Claim 1]A metal tube for heat exchange characterized by comprising the following.
A feed hole where heat exchanging fluid can circulate.
A fixed zone by which adsorption material was fixed in layers to a peripheral face.

[Claim 2]An adsorption tower which has the adsorption material which generates heat and desorbs said working fluid by carrying out an endothermic by adsorbing a working fluid.
An evaporator connected with said adsorption tower.
A condenser connected with said adsorption tower.
It was the adsorption equation heat pump provided with the above, and as it left space where said working fluid can circulate to said adsorption tower, two or more metal tubes for heat exchange according to claim 1 have been arranged in it.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application]the heat exchange this invention excelled [heat exchange] in heat exchanging efficiency — public funds — a group pipe and its heat exchange — public funds — it is related with the adsorption equation heat pump using a group pipe.
[0002]
[Description of the Prior Art]In recent years, exhaust heat of various temperature levels is discharged in large quantities from various industrial processes. Although effective thermal energy 100 ** or less occupies 3/4 or more of the total exhaust heat] especially, the actual condition is discarded while the most has not been used. The adsorption equation heat pump which uses generation of heat and the endothermic accompanying adsorption and desorption as one of the art which changes such low temperature exhaust heat into thermal energy with an expensive qualitative level is known. Since adsorption equation heat pump is provided with the feature hung up over below, useful ** of it is carried out.
** The ability degradation due to the fall of heat source temperature or a discharge is small.
** It can be operated also in a low-temperature heat source 100 ** or less.
** There are accumulation and the cold energy effect.
** The adsorption material to be used has high safety and there is no corrosiveness.
** Theoretically, don't need mechanical power.
[0003]The conventional adsorption equation heat pump chose a working fluid and adsorption material suitably, and the thing provided with the adsorption tower which has an evaporator, a condenser, and adsorption material was known. As for the adsorption tower, since powder or the shape of a grain was used abundantly as this adsorption material, it was in use to have formed with what is called a restoration method of being filled up with adsorption material with sufficient breathability.
[0004]Drawing 10 and drawing 11 explain the principle of adsorption equation heat pump. The evaporator 113 and the adsorption tower 111 are first connected for the adsorption equation heat pump 110 of drawing 10 by the valve 117, and it is made to adsorb in cooling mode until it evaporates the working fluid 119 and reaches the adsorption material 121 in the adsorption tower 111 from the evaporator 113 at the predetermined amount of adsorption. At this time, the temperature of the evaporator 113 can fall by evaporation of the working fluid 119, and the water of temperature T_a can be reduced to temperature T_{cold} through the heat exchanger in the evaporator 113. On the other hand, the heat exchanger in the adsorption tower 111 cools the adsorption material 121 by pouring the water of temperature T_a. If the amount of adsorption of the working fluid 119 reaches the specified quantity, the valve 117 will be switched, the adsorption tower 111 and the condenser 115 are connected, temperature up of the warm water of heat source temperature T_{reg} is poured and carried out to the adsorption tower 111, the working fluid 119 is desorbed from the adsorption material 121, and it is made to condense with the condenser 115. At this time, the water of temperature T_a is poured to the condenser 115. One cycle is completed in the stage which desorption ended, and an adsorption process is performed again.
[0005]The working fluid 119 is made to stick to the adsorption material 121 in temperature-up mode, connecting the adsorption tower 111 with the evaporator 113 by the valve 117 first, and pouring the warm water of heat source temperature T_s to both, as shown in drawing 11. At this time, the temperature of the adsorption tower 111 can rise with the heat of adsorption of the adsorption material 121, and temperature up of the heat source temperature T_s which flows through the inside of the adsorption tower 111 can be carried out to T_{hot}. If the amount of adsorption of the working fluid 119 reaches the specified quantity, the valve 117 will be switched, the adsorption tower 111 and the condenser 115 are connected, temperature up of the warm water of heat source temperature T_{reg} is poured and carried out to the adsorption tower 111, the working fluid 119 is desorbed from the adsorption material 121, and it is made to condense with the condenser 115. At this time, the water of temperature T_a is poured to the condenser 115. One cycle is completed in the stage which desorption ended, and an adsorption process is performed again.
[0006]
[Problem(s) to be Solved by the Invention]However, in the time which one cycle takes also in any in cooling mode and temperature-up mode, in the conventional adsorption equation heat pump, a long time had become a problem. This main cause suited that heat exchange of the adsorption material and heat exchanging fluid in an adsorption tower was not performed promptly. That is, since the adsorption tower of the conventional adsorption equation heat pump was formed by being filled up with powder or granular adsorption material, pressure loss is large, the diffusion in the adsorption tower of a working fluid becomes uneven, and the bias of the amount-of-adsorption distribution in an adsorption tower happened easily. However, the adsorption material located in the place which separated heat exchanging fluid and distance in this adsorption tower, Since it was only that the working fluid which most heat exchange with heat exchanging fluid is not performed, receives heat conduction by other adsorption material which approached, or circulates an adsorption tower receives heat conduction, when the bias of the above-mentioned amount-of-adsorption distribution arose, the long time was taken to control the inside of an adsorption tower to a predetermined temperature.

[0007]If it becomes beyond the temperature which the temperature of adsorption material set up on the occasion of adsorption, since the balance of an exoergic reaction inclines toward the system of reaction rather than a product, the adsorption capability of adsorption material will decrease, and an adsorption rate will become slow as a result. On the other hand, if the heat of heat of adsorption is not efficiently given to adsorption material in the case of desorption, the balance of an endoergic reaction will incline toward the system of reaction, and desorption speed will fall. It was rate-limiting in the time which one cycle takes to adsorption time and desorption time from such a reason by the adsorption equation heat pump which has an adsorption tower by the conventional restoration method.
[0008]In order to cancel the above technical problem, as for this invention, the adsorption and desorption of the adsorption material in an adsorption tower aim at offer of feasible adsorption equation heat pump for a short time.
[0009]
[Means for Solving the Problem and its Function]in order to solve the above-mentioned technical problem — heat exchange of the 1st invention — public funds — a group pipe makes it a gist to have a feed hole where heat exchanging fluid can circulate, and the fixed zone by which adsorption material was fixed in layers to a peripheral face.
[0010]An adsorption tower which has the adsorption material which adsorption equation heat pump of the 2nd invention generates heat by adsorbing a working fluid, and desorbs said working fluid by carrying out an endothermic, leaving space where said working fluid can circulate to said adsorption tower in adsorption equation heat pump provided with an evaporator connected with said adsorption tower, and a condenser connected with said adsorption tower — heat exchange of the 1st invention — public funds — let it be a gist to have arranged a group pipe.
[0011]Hereafter, composition and an operation of this invention are explained in full detail. first — heat exchange of the 1st invention — public funds — a group pipe is explained. Although a kind in particular of metal tube to be used is not limited, copper, stainless steel, aluminum of an alloy having contained these, etc. are preferred, and that of especially copper are preferred, for example. Although not limited in particular except being the structure of having a feed hole where heat exchanging fluid can circulate, a metal tube is preferred especially from a point of heat exchanging efficiency, when it is fin tube structure, for example.
[0012]Although not limited especially as adsorption material, silica gel, activated alumina, activated carbon, zeolite, molecular sieving carbon, etc. are preferred, for example, and especially silica gel and activated carbon are preferred. About the physical properties of adsorption material, it is preferred that it is more than particle diameter of 2 mm or less, 0.3 or more ml/g of pore volume, and specific surface area ^{2}[of 600 m]/g.
[0013]Since thickness of a fixed zone when adsorption material is fixed to a metal tube peripheral face does not produce temperature distribution of a degree very much between a portion and a peripheral face of a fixed zone in contact with a metaled peripheral face, it is preferred that it is 1-6 mm, and it is preferred that it is especially 2-3 mm. If there is a problem in intensity when fabricating a fixed zone when thickness becomes below a minimum, and it becomes beyond a maximum, it will be apprehensive about a bias of distribution of decline in efficiency of heat exchange with heat exchanging fluid and the amount of adsorption within a fixed zone becoming very large to a degree etc.
[0014]Although a forming process in particular of a fixed zone is not limited, after applying to a metal tube peripheral face a thing which made adsorption material contain a synthetic resin for adhesion, a method of fabricating a layer by calcination, etc. are common. About heat exchanging fluid, as long as it is usually used, it may be used regardless of a fluid and a gas, but as a fluid, water, oil, etc. are preferred and air, nitrogen, carbon dioxide, etc. are preferred as a gas.
[0015]heat exchange of the 1st invention — public funds — if a group pipe is used, since the heat exchange of that the thermal conductivity of a metal tube is high and the fixed zone can be carried out at heat exchanging fluid which flows through a feed hole of a metal tube, and a sufficiently quick speed, it becomes possible to carry out temperature control of the adsorption material formed in a peripheral face of a metal tube as a fixed zone promptly with heat exchanging fluid.
[0016]Then, adsorption equation heat pump of the 2nd invention is explained. What is necessary is just usable to the usual adsorption equation heat pump in a working fluid used for adsorption equation heat pump of the 2nd invention, and water, lower alcohol, aromatic hydrocarbon, ammonia, acetone, etc. are mentioned. Water and ethanol are preferred when the latent heat of vaporization, steam pressure, toxicity, etc. are especially taken into consideration.
[0017]an adsorption tower leaves space where a working fluid can circulate — heat exchange of two or more 1st inventions — public funds, although a group pipe is arranged. Space where a working fluid can circulate here means space where it is sufficient although a working fluid desorbed from a working fluid or adsorption material evaporated in an evaporator can diffuse the whole inside of an adsorption tower uniformly. By existence of this space, a bias of amount-of-adsorption distribution of shaft orientations in an adsorption tower decreases, and adsorption and desorption time of adsorption material can be shortened.
[0018]heat of adsorption which adsorption equation heat pump of the 2nd invention generates in an adsorption process in cooling mode or temperature-up mode when adsorption material in an adsorption tower adsorbs a working fluid — heat exchange of the 1st invention — public funds — it can remove from adsorption material very promptly by using a group pipe. As a result, the predetermined amount of adsorption can be reached promptly, without reducing an adsorption rate. In a desorption process, since quantity of heat which is equivalent to heat of adsorption from heat exchanging fluid can be promptly given to adsorption material, adsorption material is promptly renewable.
[0019]
[Example]The suitable example of this invention is described below. The adsorption equation heat pump 10 of the 1st example is shown in drawing 1. The composition of this example consists of the adsorption tower 1, the evaporator/condenser 3, and the interconnecting tube 5. Silica gel was used as adsorption material, water was used for the adsorption system as a working fluid, and the water set as prescribed temperature was used for heat exchanging fluid.
[0020]In this example, we did not make an evaporator and a condenser separate composition, but decided to use the same apparatus properly to an evaporator or a condenser according to the purpose of use, and this apparatus was made into the evaporator / condenser 3. This evaporator / condenser 3 consist of a heat insulation well-closed container which has the safety valve 7 which opens by overpressure. In order to perform the water and heat exchange as a working fluid which exist in an inside, the heat exchange pipe 9 is allocated. The heat exchange pipe 9 has the entrance 9a and the exit 9b, and can circulate water with circulation or a circulating pump as heat exchanging fluid, and also can set inlet temperature as a predetermined temperature. The effective evaporation area of an evaporator / condenser 3 is 0.0314-m^2.

[0021]the adsorption tower 1 has the safety valve 6 which opens by overpressure, and consists of a with 133 mm in inside diameter, and an outer diameter of 165.2 mm heat insulation well-closed container — two or more heat exchange [inside] — public funds — as the group pipe 11 (after-mentioned) leaves the space where the water as a working fluid can circulate, it is arranged. this adsorption tower 1 — 115 heat exchange — public funds — consisting of the group pipe 11 — the heat exchange from the entrance 1a of heat exchanging fluid — public funds — pass the feed hole 13 of the group pipe 11 — the temperature of the adsorption material 14 shown in drawing 2 can be adjusted now by circulating water to the exit 1b. The water as this heat exchanging fluid can set inlet temperature as a predetermined temperature. The metal tube 11 for heat exchange is explained in full detail here.
[0022]The metal tube 11 for heat exchange has the feed hole 13 where heat exchanging fluid can circulate, and the fixed zone 15 by which the adsorption material 14 was fixed to the peripheral face, as shown in drawing 2. using the with 4 mm in inside diameter, and an outer diameter of 6 mm copper pipe 17 in this example — as the adsorption material 14 — the silica gel C (the product made from Fuji DEVISON Chemicals.) Specific surface area $721x10^{3}m^{2}/kg$, and pore volume $0.42x10^{-3}m^{3}/kg$ are ground to 42 meshes (particle diameter of 355 micrometers or less), By mixing a vinyl acetate system binder, pasting the peripheral face of said copper pipe 17, and calcinating in 110 ** for 6 hours, the fixed zone 15 2 mm in thickness and 400 mm in length was formed. The specific surface areas of this fixed zone 15 were $200x10^{3}m^{2}/kg$, and pore volume was $0.12x10^{-3}m^{3}$ / kg (all are computed by the B.E.T method). The adsorption isotherm (it measures at the temperature of 30 **) of this fixed zone 15 is shown in drawing 3.
[0023]The interconnecting tube 5 has connected both so that the water which is a working fluid can come and go the inside of an evaporator / condenser 3, and the adsorption tower 1. Since the interconnecting tube 5 has a course which leads to the vacuum pump 4 besides the course which connects the adsorption tower 1 with an evaporator / condenser 3, it forms a three-forked road, and it has the three valves 5a, 5b, and 5c which make it possible to seal each independently.
[0024]The case where the adsorption equation heat pump 10 of this example which consists of the above composition is used by cooling mode is taken for an example, and the operation and an effect are explained in full detail below. the adsorption equation heat pump 10 of this example — heat exchange — public funds — the fixed zone of the group pipe 11 — 15 skin temperature (position of (A) in drawing 2), The applicable position was equipped with measuring equipment so that measurement with the passage of time might be respectively attained in the entrance temperature of the heat exchanging fluid which circulates the skin temperature (position of (B) in drawing 2) of the copper pipe 17, the temperature of the working fluid of an evaporator / condenser 3 inside, the adsorption tower 1, and the evaporator/condenser 3.
The following pretreatments were performed before operating the adsorption equation heat pump 10 of <adsorption test> this example. first — water with a temperature [the entrance 1a of heat exchanging fluid to] of 80 ** — heat exchange — public funds — the vacuum deairing of the inside of the adsorption tower 1 was carried out by closing the valve 5b and opening the valves 5a and 5c, circulating to the feed hole 13 of the group pipe 11. Next, by closing the valve 5a and opening the valves 5b and 5c, the evaporator / condenser 3 was deaerated, the impure component of the water which is a working fluid was removed, and the valves 5b and 5c were closed.
[0025]Subsequently, water with a temperature of 10 ** was circulated by the amount of water of $1.6x10^{-4}m^{3}/s$ and $1.4x10^{-4}m^{3}/s$ as heat exchanging fluid of the adsorption tower 1, respectively considering water with a temperature of 30 ** as heat exchanging fluid of an evaporator / condenser 3. After checking that fixed zone 15 skin temperature of the metal tube 11 for heat exchange, the skin temperature of the copper pipe 17, and the temperature of the working fluid of an evaporator / condenser 3 inside have reached prescribed temperature, the valves 5a and 5b were opened, the steam of water was introduced into adsorption tower 1 inside as a working fluid, and adsorption was started. The variation of the X-axis and temperature was taken for the lapsed time after an adsorption start to the Y-axis, and the temperature change (it displays by -) in the position of (B) in the temperature change (it displays by O) in the position of (A) in drawing 2 and drawing 2 and the temperature change (it displays by <>) in the exit of the heat exchanging fluid which circulates the adsorption tower 1 were shown in drawing 4, respectively.
Following the <desorption examination> adsorption test, water with a temperature of 70 ** was circulated as heat exchanging fluid of the adsorption tower 1, water with a temperature of 30 ** was circulated as heat exchanging fluid of an evaporator / condenser 3, and the desorption examination was done. The variation of the X-axis and temperature was taken for the lapsed time after a desorption start to the Y-axis, and the temperature change (it displays by -) in the position of (B) in the temperature change (it displays by O) in the position of (A) in drawing 2 and drawing 2 and the temperature change (it displays by <>) in the exit of the heat exchanging fluid which circulates the adsorption tower 1 were shown in drawing 5, respectively.
[0026]Next, adsorption and a desorption examination were done using the adsorption equation heat pump 50 (drawing 6) of the type which replaced the adsorption tower 1 of the adsorption equation heat pump 10 of the 1st example by the restoration type adsorption tower as the 1st comparative example. This adsorption tower 51 has double tube structure, and can adjust the temperature of the adsorption material 53 now by circulating water from the entrance 51a of heat exchanging fluid to the exit 51b through the outer tube 51c of a double tube. The adsorption tower 51 is cylindrical shape with a 54 mm[in inside diameter] x length of 200 mm, and carried out random restoration of the silica gel A (product made from Fuji DEVISON Chemicals) as the adsorption material 53 at the inner tube 51d of the adsorption tower 51. Specific surface area is [$721x10^{-3}m^{2}/kg$, and the pore volume of the physical properties of the silica gel A] $0.43x10^{3}m^{3}/kg$.
[0027]By the adsorption test by this adsorption equation heat pump 50, the water temperature which circulates 30 **, and the evaporator/condenser 3 in the water temperature which circulates the adsorption tower 51 was set as 25 **, and the water temperature which circulates 60 **, and the evaporator/condenser 3 in the water temperature which circulates the adsorption tower 51 was set as 30 ** by the desorption examination. After the adsorption test performed the same pretreatment as the 1st example, it was carried out. The variation of the temperature of the X-axis and adsorption material was taken for the lapsed time after the adsorption-and-desorption start in an adsorption test and a desorption examination to the Y-axis, and the temperature change in the position [in / for the temperature change in the position / in / for the temperature change in the position of (a) in drawing 6 / ** and drawing 6 / of (b) / O and drawing 6] of (c) was displayed on drawing 7 and drawing 8 by **.
[0028]The result of adsorption with the 1st example and a comparative example and a desorption examination was summarized in Table 1.

[0029]
[Table 1]

	第１実施例	第１比較例
＜吸着試験＞		
吸着に要する時間（h）	１．５	＞１０
吸着材の最大温度変化（K）	８	５０
吸着材の最大温度分布幅（K）	６	４５
＜脱着試験＞		
脱着に要する時間（h）	０．５	＞ ６
吸着材の最大温度変化（K）	８	１３
吸着材の最大温度分布幅（K）	５	１２
１サイクルに要する時間（h）	２．０	＞１６

[0030]In the adsorption material (drawing 6 (a)) located in center-section shaft orientations in early stages of adsorption and desorption, the maximum temperature change of adsorption material was recorded [in the 1st example] in the fixed zone surface in early stages of adsorption and desorption (drawing 2 (A)), respectively by the 1st comparative example. This figure serves as an index whether heat exchange was performed efficiently, after adsorption material carries out the adsorption and desorption of the working fluid and a temperature change arises.
[0031]The temperature distribution width of adsorption material is the temperature gradient produced in the 1st example between the fixed zone surface (drawing 2 (A)) and the metal tube surface (drawing 2 (B)).
It is the temperature gradient produced between the adsorption material (drawing 6 (a)) located in center-section shaft orientations in the 1st comparative example, and the adsorption material (drawing 6 (c)) located near the adsorption tower heat exchanging fluid.
Each recorded the maximum temperature distribution width in the early stages of adsorption and desorption. This figure serves as [whether whether post heating exchange which adsorption material's carried out the adsorption and desorption of the working fluid, and the temperature change produced being performed efficiently, and a working fluid diffused the inside of an adsorption tower uniformly, and the bias has arisen in amount-of-adsorption distribution, and] an index of **.
[0032]Compared with the 1st comparative example, the maximum temperature distribution width of the maximum temperature change of adsorption material and adsorption material of the adsorption equation heat pump of the 1st example is small so that clearly from Table 1. This result shows that post heating exchange which adsorption material carried out the adsorption and desorption of the working fluid, and the temperature change produced was performed efficiently, and also that a working fluid diffuses the inside of an adsorption tower uniformly, and the big bias has not arisen in amount-of-adsorption distribution.
[0033]In the 1st example, compared with the 1st comparative example, adsorption and desorption time can be shortened extremely and one cycle can be performed now in a short time. Next, the adsorption equation heat pump of the 2nd example is explained. the heat exchange used for the adsorption equation heat pump 10 of the 1st example although the adsorption equation heat pump in particular of the 2nd example itself did not illustrate — public funds — the heat exchange which was replaced with the group pipe 11 and illustrated to drawing 9 — public funds — it is the same composition as the adsorption equation heat pump 10 of the 1st example except having used the group pipe 16. heat exchange — public funds — except for the copper pipe 18 wearing or really formed in the outside surface in the fin 18a having been used for the group pipe 16 — heat exchange — public funds — it manufactured like the group pipe 11.
[0034]the adsorption equation heat pump of the 2nd example — existence of the fin 18a — heat exchange — public funds — the thermal conductivity of the group pipe 16 improved more, and the heat exchanging efficiency of the fixed zone 15 and the heat exchanging fluid which flows through the feed hole 13 improved further compared with the 1st example. For this reason, although it could not be overemphasized that it had the same effect as the adsorption equation heat pump 10 of the 1st example by the adsorption equation heat pump of the 2nd example, in connection with adsorption and desorption time having been shortened further, one cycle could be performed further in a short time.
[0035]as explained in full detail above, the adsorption equation heat pump of the 2nd invention leaves the space where a working fluid can circulate to an adsorption tower — the heat exchange of two or more 1st inventions — public funds — the time which one cycle takes became very short by having arranged the group pipe. It cannot be overemphasized that it can carry out in various modes in the range which this invention is not limited to the above-mentioned example at all, and does not deviate from the meaning of this invention. For example, although the 1st example explained cooling mode, it completely has the same composition and operation also about temperature-up mode, and has the effect that the time which one cycle takes becomes very short.
[0036]

[Effect of the Invention]it explained in full detail above — as — the heat exchange of the 1st invention — public funds — according to the group pipe, the thermal conductivity of a metal tube is high. Since the heat exchange of the fixed zone can be carried out at the heat exchanging fluid which flows through the feed hole of a metal tube, and a sufficiently quick speed, it becomes possible to carry out temperature control of the adsorption material formed in the peripheral face of a metal tube as a fixed zone promptly with heat exchanging fluid.
[0037]the adsorption equation heat pump of the 2nd invention leaves the space where a working fluid can circulate to an adsorption tower — the heat exchange of two or more 1st inventions — public funds — by having arranged the group pipe, the adsorption and desorption of the adsorption material in an adsorption tower became feasible for a short time. As a result in cooling mode and temperature-up mode, the time which one cycle takes became very short.

[Translation done.]

TECHNICAL FIELD

[Industrial Application]the heat exchange this invention excelled [heat exchange] in heat exchanging efficiency — public funds — a group pipe and its heat exchange — public funds — it is related with the adsorption equation heat pump using a group pipe.

[Translation done.]

PRIOR ART

[Description of the Prior Art]In recent years, exhaust heat of various temperature levels is discharged in large quantities from various industrial processes. Although effective thermal energy 100 ** or less occupies 3/4 or more of the total exhaust heat] especially, the actual condition is discarded while the most has not been used. The adsorption equation heat pump which uses generation of heat and the endothermic accompanying adsorption and desorption as one of the art which changes such low temperature exhaust heat into thermal energy with an expensive qualitative level is known. Since adsorption equation heat pump is provided with the feature hung up over below, useful ** of it is carried out.
** The ability degradation due to the fall of heat source temperature or a discharge is small.
** It can be operated also in a low-temperature heat source 100 ** or less.
** There are accumulation and the cold energy effect.
** The adsorption material to be used has high safety and there is no corrosiveness.
** Theoretically, don't need mechanical power.
[0003]The conventional adsorption equation heat pump chose a working fluid and adsorption material suitably, and the thing provided with the adsorption tower which has an evaporator, a condenser, and adsorption material was known. As for the adsorption tower, since powder or the shape of a grain was used abundantly as this adsorption material, it was in use to have formed with what is called a restoration method of being filled up with adsorption material with sufficient breathability.
[0004]Drawing 10 and drawing 11 explain the principle of adsorption equation heat pump. The evaporator 113 and the adsorption tower 111 are first connected for the adsorption equation heat pump 110 of drawing 10 by the valve 117, and it is made to adsorb in cooling mode until it evaporates the working fluid 119 and reaches the adsorption material 121 in the adsorption tower 111 from the evaporator 113 at the predetermined amount of adsorption. At this time, the temperature of the evaporator 113 can fall by evaporation of the working fluid 119, and the water of temperature T_a can be reduced to temperature T_{cold} through the heat exchanger in the evaporator 113. On the other hand, the heat exchanger in the adsorption tower 111 cools the adsorption material 121 by pouring the water of temperature T_a. If the amount of adsorption of the working fluid 119 reaches the specified quantity, the valve 117 will be switched, the adsorption tower 111 and the condenser 115 are connected, temperature up of the warm water of heat source temperature T_{reg} is poured and carried out to the adsorption tower 111, the working fluid 119 is desorbed from the adsorption material 121, and it is made to condense with the condenser 115. At this time, the water of temperature T_a is poured to the condenser 115. One cycle is completed in the stage which desorption ended, and an adsorption process is performed again.
[0005]The working fluid 119 is made to stick to the adsorption material 121 in temperature-up mode, connecting the adsorption tower 111 with the evaporator 113 by the valve 117 first, and pouring the warm water of heat source temperature T_s to both, as shown in drawing 11. At this time, the temperature of the adsorption tower 111 can rise with the heat of adsorption of the adsorption material 121, and temperature up of the heat source temperature T_s which flows through the inside of the adsorption tower 111 can be carried out to T_{hot}. If the amount of adsorption of the working fluid 119 reaches the specified quantity, the valve 117 will be switched, the adsorption tower 111 and the condenser 115 are connected, temperature up of the warm water of heat source temperature T_{reg} is poured and carried out to the adsorption tower 111, the working fluid 119 is desorbed from the adsorption material 121, and it is made to condense with the condenser 115. At this time, the water of temperature T_a is poured to the condenser 115. One cycle is completed in the stage which desorption ended, and an adsorption process is performed again.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention]it explained in full detail above — as — the heat exchange of the 1st invention — public funds — according to the group pipe, the thermal conductivity of a metal tube is high. Since the heat exchange of the fixed zone can be carried out at the heat exchanging fluid which flows through the feed hole of a metal tube, and a sufficiently quick speed, it becomes possible to carry out temperature control of the adsorption material formed in the peripheral face of a metal tube as a fixed zone promptly with heat exchanging fluid.
[0037]the adsorption equation heat pump of the 2nd invention leaves the space where a working fluid can circulate to an adsorption tower — the heat exchange of two or more 1st inventions — public funds — by having arranged the group pipe, the adsorption and desorption of the adsorption material in an adsorption tower became feasible for a short time. As a result in cooling mode and temperature-up mode, the time which one cycle takes became very short.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention]However, in the time which one cycle takes also in any in cooling mode and temperature-up mode, in the conventional adsorption equation heat pump, a long time had become a problem. This main cause suited that heat exchange of the adsorption material and heat exchanging fluid in an adsorption tower was not performed promptly. That is, since the adsorption tower of the conventional adsorption equation heat pump was formed by being filled up with powder or granular adsorption material, pressure loss is large, the diffusion in the adsorption tower of a working fluid becomes uneven, and the bias of the amount-of-adsorption distribution in an adsorption tower happened easily. However, the adsorption material located in the place which separated heat exchanging fluid and distance in this adsorption tower, Since it was only that the working fluid which most heat exchange with heat exchanging fluid is not performed, receives heat conduction by other adsorption material which approached, or circulates an adsorption tower receives heat conduction, when the bias of the above-mentioned amount-of-adsorption distribution arose, the long time was taken to control the inside of an adsorption tower to a predetermined temperature.
[0007]If it becomes beyond the temperature which the temperature of adsorption material set up on the occasion of adsorption, since the balance of an exoergic reaction inclines toward the system of reaction rather than a product, the adsorption capability of adsorption material will decrease, and an adsorption rate will become slow as a result. On the other hand, if the heat of heat of adsorption is not efficiently given to adsorption material in the case of desorption, the balance of an endoergic reaction will incline toward the system of reaction, and desorption speed will fall. It was rate-limiting in the time which one cycle takes to adsorption time and desorption time from such a reason by the adsorption equation heat pump which has an adsorption tower by the conventional restoration method.
[0008]In order to cancel the above technical problem, as for this invention, the adsorption and desorption of the adsorption material in an adsorption tower aim at offer of feasible adsorption equation heat pump for a short time.

[Translation done.]

OPERATION

[Means for Solving the Problem and its Function]in order to solve the above-mentioned technical problem — heat exchange of the 1st invention — public funds — a group pipe makes it a gist to have a feed hole where heat exchanging fluid can circulate, and the fixed zone by which adsorption material was fixed in layers to a peripheral face.
[0010]An adsorption tower which has the adsorption material which adsorption equation heat pump of the 2nd invention generates heat by adsorbing a working fluid, and desorbs said working fluid by carrying out an endothermic, leaving space where said working fluid can circulate to said adsorption tower in adsorption equation heat pump provided with an evaporator connected with said adsorption tower, and a condenser connected with said adsorption tower — heat exchange of the 1st invention — public funds — let it be a gist to have arranged a group pipe.
[0011]Hereafter, composition and an operation of this invention are explained in full detail. first — heat exchange of the 1st invention — public funds — a group pipe is explained. Although a kind in particular of metal tube to be used is not limited, copper, stainless steel, aluminum of an alloy having contained these, etc. are preferred, and that of especially copper are preferred, for example. Although not limited in particular except being the structure of having a feed hole where heat exchanging fluid can circulate, a metal tube is preferred especially from a point of heat exchanging efficiency, when it is fin tube structure, for example.
[0012]Although not limited especially as adsorption material, silica gel, activated alumina, activated carbon, zeolite, molecular sieving carbon, etc. are preferred, for example, and especially silica gel and activated carbon are preferred. About the physical properties of adsorption material, it is preferred that it is more than particle diameter of 2 mm or less, 0.3 or more ml/g of pore volume, and specific surface area ^{2}[of 600 m]/g.
[0013]Since thickness of a fixed zone when adsorption material is fixed to a metal tube peripheral face does not produce temperature distribution of a degree very much between a portion and a peripheral face of a fixed zone in contact with a metaled peripheral face, it is preferred that it is 1-6 mm, and it is preferred that it is especially 2-3 mm. If there is a problem in intensity when fabricating a fixed zone when thickness becomes below a minimum, and it becomes beyond a maximum, it will be apprehensive about a bias of distribution of decline in efficiency of heat exchange with heat exchanging fluid and the amount of adsorption within a fixed zone becoming very large to a degree etc.
[0014]Although a forming process in particular of a fixed zone is not limited, after applying to a metal tube peripheral face a thing which made adsorption material contain a synthetic resin for adhesion, a method of fabricating a layer by calcination, etc. are common. About heat exchanging fluid, as long as it is usually used, it may be used regardless of a fluid and a gas, but as a fluid, water, oil, etc. are preferred and air, nitrogen, carbon dioxide, etc. are preferred as a gas.
[0015]heat exchange of the 1st invention — public funds — if a group pipe is used, since the heat exchange of that the thermal conductivity of a metal tube is high and the fixed zone can be carried out at heat exchanging fluid which flows through a feed hole of a metal tube, and a sufficiently quick speed, it becomes possible to carry out temperature control of the adsorption material formed in a peripheral face of a metal tube as a fixed zone promptly with heat exchanging fluid.
[0016]Then, adsorption equation heat pump of the 2nd invention is explained. What is necessary is just usable to the usual adsorption equation heat pump in a working fluid used for adsorption equation heat pump of the 2nd invention, and water, lower alcohol, aromatic hydrocarbon, ammonia, acetone, etc. are mentioned. Water and ethanol are preferred when the latent heat of vaporization, steam pressure, toxicity, etc. are especially taken into consideration.
[0017]an adsorption tower leaves space where a working fluid can circulate — heat exchange of two or more 1st inventions — public funds, although a group pipe is arranged. Space where a working fluid can circulate here means space where it is sufficient although a working fluid desorbed from a working fluid or adsorption material evaporated in an evaporator can diffuse the whole inside of an adsorption tower uniformly. By existence of this space, a bias of amount-of-adsorption distribution of shaft orientations in an adsorption tower decreases, and adsorption and desorption time of adsorption material can be shortened.
[0018]heat of adsorption which adsorption equation heat pump of the 2nd invention generates in an adsorption process in cooling mode or temperature-up mode when adsorption material in an adsorption tower adsorbs a working fluid — heat exchange of the 1st invention — public funds — it can remove from adsorption material very promptly by using a group pipe. As a result, the predetermined amount of adsorption can be reached promptly, without reducing an adsorption rate. In a desorption process, since quantity of heat which is equivalent to heat of adsorption from heat exchanging fluid can be promptly given to adsorption material, adsorption material is promptly renewable.

~~[Translation done.]~~

EXAMPLE

[Example]The suitable example of this invention is described below. The adsorption equation heat pump 10 of the 1st example is shown in drawing 1. The composition of this example consists of the adsorption tower 1, the evaporator/condenser 3, and the interconnecting tube 5. Silica gel was used as adsorption material, water was used for the adsorption system as a working fluid, and the water set as prescribed temperature was used for heat exchanging fluid.

[0020]In this example, we did not make an evaporator and a condenser separate composition, but decided to use the same apparatus properly to an evaporator or a condenser according to the purpose of use, and this apparatus was made into the evaporator / condenser 3. This evaporator / condenser 3 consist of a heat insulation well-closed container which has the safety valve 7 which opens by overpressure. In order to perform the water and heat exchange as a working fluid which exist in an inside, the heat exchange pipe 9 is allocated. The heat exchange pipe 9 has the entrance 9a and the exit 9b, and can circulate water with circulation or a circulating pump as heat exchanging fluid, and also can set inlet temperature as a predetermined temperature. The effective evaporation area of an evaporator / condenser 3 is $0.0314\text{-}m^2$.

[0021]the adsorption tower 1 has the safety valve 6 which opens by overpressure, and consists of a with 133 mm in inside diameter, and an outer diameter of 165.2 mm heat insulation well-closed container — two or more heat exchange [inside] — public funds — as the group pipe 11 (after-mentioned) leaves the space where the water as a working fluid can circulate, it is arranged. this adsorption tower 1 — 115 heat exchange — public funds — consisting of the group pipe 11 — the heat exchange from the entrance 1a of heat exchanging fluid — public funds — pass the feed hole 13 of the group pipe 11 — the temperature of the adsorption material 14 shown in drawing 2 can be adjusted now by circulating water to the exit 1b. The water as this heat exchanging fluid can set inlet temperature as a predetermined temperature. The metal tube 11 for heat exchange is explained in full detail here.

[0022]The metal tube 11 for heat exchange has the feed hole 13 where heat exchanging fluid can circulate, and the fixed zone 15 by which the adsorption material 14 was fixed to the peripheral face, as shown in drawing 2. using the with 4 mm in inside diameter, and an outer diameter of 6 mm copper pipe 17 in this example — as the adsorption material 14 — the silica gel C (the product made from Fuji DEVISON Chemicals.) Specific surface area $721\text{x}10^{3}m^2/kg$, and pore volume $0.42\text{x}10^{-3}m^3/kg$ are ground to 42 meshes (particle diameter of 355 micrometers or less). By mixing a vinyl acetate system binder, pasting the peripheral face of said copper pipe 17, and calcinating in 110 ** for 6 hours, the fixed zone 15 2 mm in thickness and 400 mm in length was formed. The specific surface areas of this fixed zone 15 were $200\text{x}10^{3}m^2/kg$, and pore volume was $0.12\text{x}10^{-3}m^3$ / kg (all are computed by the B.E.T method). The adsorption isotherm (it measures at the temperature of 30 **) of this fixed zone 15 is shown in drawing 3.

[0023]The interconnecting tube 5 has connected both so that the water which is a working fluid can come and go the inside of an evaporator / condenser 3, and the adsorption tower 1. Since the interconnecting tube 5 has a course which leads to the vacuum pump 4 besides the course which connects the adsorption tower 1 with an evaporator / condenser 3, it forms a three-forked road, and it has the three valves 5a, 5b, and 5c which make it possible to seal each independently.

[0024]The case where the adsorption equation heat pump 10 of this example which consists of the above composition is used by cooling mode is taken for an example, and the operation and an effect are explained in full detail below. the adsorption equation heat pump 10 of this example — heat exchange — public funds — the fixed zone of the group pipe 11 — 15 skin temperature (position of (A) in drawing 2), The applicable position was equipped with measuring equipment so that measurement with the passage of time might be respectively attained in the entrance temperature of the heat exchanging fluid which circulates the skin temperature (position of (B) in drawing 2) of the copper pipe 17, the temperature of the working fluid of an evaporator / condenser 3 inside, the adsorption tower 1, and the evaporator/condenser 3.

The following pretreatments were performed before operating the adsorption equation heat pump 10 of <adsorption test> this example. first — water with a temperature [the entrance 1a of heat exchanging fluid to] of 80 ** — heat exchange — public funds — the vacuum deairing of the inside of the adsorption tower 1 was carried out by closing the valve 5b and opening the valves 5a and 5c, circulating to the feed hole 13 of the group pipe 11. Next, by closing the valve 5a and opening the valves 5b and 5c, the evaporator / condenser 3 was deaerated, the impure component of the water which is a working fluid was removed, and the valves 5b and 5c were closed.

[0025]Subsequently, water with a temperature of 10 ** was circulated by the amount of water of $1.6\text{x}10^{-4}m^3/s$ and $1.4\text{x}10^{-4}m^3/s$ as heat exchanging fluid of the adsorption tower 1, respectively considering water with a temperature of 30 ** as heat exchanging fluid of an evaporator / condenser 3. After checking that fixed zone 15 skin temperature of the metal tube 11 for heat exchange, the skin temperature of the copper pipe 17, and the temperature of the working fluid of an evaporator / condenser 3 inside have reached prescribed temperature, the valves 5a and 5b were opened, the steam of water was introduced into adsorption tower 1 inside as a working fluid, and adsorption was started. The variation of the X-axis and temperature was taken for the lapsed time after an adsorption start to the Y-axis, and the temperature change (it displays by -) in the position of (B) in the temperature change (it displays by O) in the position of (A) in drawing 2 and drawing 2 and the temperature change (it displays by <>) in the exit of the heat exchanging fluid which circulates the adsorption tower 1 were shown in drawing 4, respectively.

Following the <desorption examination> adsorption test, water with a temperature of 70 ** was circulated as heat

exchanging fluid of the adsorption tower 1, water with a temperature of 30 ** was circulated as heat exchanging fluid of an evaporator / condenser 3, and the desorption examination was done. The variation of the X-axis and temperature was taken for the lapsed time after a desorption start to the Y-axis, and the temperature change (it displays by -) in the position of (B) in the temperature change (it displays by O) in the position of (A) in drawing 2 and drawing 2 and the temperature change (it displays by <>) in the exit of the heat exchanging fluid which circulates the adsorption tower 1 were shown in drawing 5, respectively.

[0026]Next, adsorption and a desorption examination were done using the adsorption equation heat pump 50 (drawing 6) of the type which replaced the adsorption tower 1 of the adsorption equation heat pump 10 of the 1st example by the restoration type adsorption tower as the 1st comparative example. This adsorption tower 51 has double tube structure, and can adjust the temperature of the adsorption material 53 now by circulating water from the entrance 51a of heat exchanging fluid to the exit 51b through the outer tube 51c of a double tube. The adsorption tower 51 is cylindrical shape with a 54 mm[in inside diameter] x length of 200 mm, and carried out random restoration of the silica gel A (product made from Fuji DEVISON Chemicals) as the adsorption material 53 at the inner tube 51d of the adsorption tower 51. Specific surface area is [721x10 $^{-3}$m^{2}/kg, and the pore volume of the physical properties of the silica gel A] 0.43x10 ^{3}m^{3}/kg.

[0027]By the adsorption test by this adsorption equation heat pump 50, the water temperature which circulates 30 **, and the evaporator/condenser 3 in the water temperature which circulates the adsorption tower 51 was set as 25 **, and the water temperature which circulates 60 **, and the evaporator/condenser 3 in the water temperature which circulates the adsorption tower 51 was set as 30 ** by the desorption examination. After the adsorption test performed the same pretreatment as the 1st example, it was carried out. The variation of the temperature of the X-axis and adsorption material was taken for the lapsed time after the adsorption-and-desorption start in an adsorption test and a desorption examination to the Y-axis, and the temperature change in the position [in / for the temperature change in the position / in / for the temperature change in the position of (a) in drawing 6 / ** and drawing 6 / of (b) / O and drawing 6] of (c) was displayed on drawing 7 and drawing 8 by **.

[0028]The result of adsorption with the 1st example and a comparative example and a desorption examination was summarized in Table 1.

[0029]

[Table 1]

	第１実施例	第１比較例
<吸着試験>		
吸着に要する時間（ｈ）	１．５	＞１０
吸着材の最大温度変化（Ｋ）	８	５０
吸着材の最大温度分布幅（Ｋ）	６	４５
<脱着試験>		
脱着に要する時間（ｈ）	０．５	＞　６
吸着材の最大温度変化（Ｋ）	８	１３
吸着材の最大温度分布幅（Ｋ）	５	１２
１サイクルに要する時間（ｈ）	２．０	＞１６

[0030]In the adsorption material (drawing 6 (a)) located in center-section shaft orientations in early stages of adsorption and desorption, the maximum temperature change of adsorption material was recorded [in the 1st example] in the fixed zone surface in early stages of adsorption and desorption (drawing 2 (A)), respectively by the 1st comparative example. This figure serves as an index whether heat exchange was performed efficiently, after adsorption material carries out the adsorption and desorption of the working fluid and a temperature change arises.

[0031]The temperature distribution width of adsorption material is the temperature gradient produced in the 1st example between the fixed zone surface (drawing 2 (A)) and the metal tube surface (drawing 2 (B)).
It is the temperature gradient produced between the adsorption material (drawing 6 (a)) located in center-section shaft orientations in the 1st comparative example, and the adsorption material (drawing 6 (c)) located near the adsorption tower heat exchanging fluid.
Each recorded the maximum temperature distribution width in the early stages of adsorption and desorption. This figure serves as [whether whether post heating exchange which adsorption material's carried out the adsorption and desorption of the working fluid, and the temperature change produced being performed efficiently, and a working fluid diffused the inside of an adsorption tower uniformly, and the bias has arisen in amount-of-adsorption distribution, and] an index of **.

[0032]Compared with the 1st comparative example, the maximum temperature distribution width of the maximum temperature change of adsorption material and adsorption material of the adsorption equation heat pump of the 1st example is small so that clearly from Table 1. This result shows that post heating exchange which adsorption material

carried out the adsorption and desorption of the working fluid, and the temperature change produced was performed efficiently, and also that a working fluid diffuses the inside of an adsorption tower uniformly, and the big bias has not arisen in amount-of-adsorption distribution.

[0033]In the 1st example, compared with the 1st comparative example, adsorption and desorption time can be shortened extremely and one cycle can be performed now in a short time. Next, the adsorption equation heat pump of the 2nd example is explained. the heat exchange used for the adsorption equation heat pump 10 of the 1st example although the adsorption equation heat pump in particular of the 2nd example itself did not illustrate -- public funds -- the heat exchange which was replaced with the group pipe 11 and illustrated to drawing 9 -- public funds -- it is the same composition as the adsorption equation heat pump 10 of the 1st example except having used the group pipe 16. heat exchange -- public funds -- except for the copper pipe 18 wearing or really formed in the outside surface in the fin 18a having been used for the group pipe 16 -- heat exchange -- public funds -- it manufactured like the group pipe 11.

[0034]the adsorption equation heat pump of the 2nd example -- existence of the fin 18a -- heat exchange -- public funds -- the thermal conductivity of the group pipe 16 improved more, and the heat exchanging efficiency of the fixed zone 15 and the heat exchanging fluid which flows through the feed hole 13 improved further compared with the 1st example. For this reason, although it could not be overemphasized that it had the same effect as the adsorption equation heat pump 10 of the 1st example by the adsorption equation heat pump of the 2nd example, in connection with adsorption and desorption time having been shortened further, one cycle could be performed further in a short time.

[0035]as explained in full detail above, the adsorption equation heat pump of the 2nd invention leaves the space where a working fluid can circulate to an adsorption tower -- the heat exchange of two or more 1st inventions -- public funds -- the time which one cycle takes became very short by having arranged the group pipe. It cannot be overemphasized that it can carry out in various modes in the range which this invention is not limited to the above-mentioned example at all, and does not deviate from the meaning of this invention. For example, although the 1st example explained cooling mode, it completely has the same composition and operation also about temperature-up mode, and has the effect that the time which one cycle takes becomes very short.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1]It is an explanatory view showing the adsorption equation heat pump of the 1st example.
[Drawing 2]the heat exchange used for the adsorption equation heat pump of the 1st example — public funds — it is drawing of longitudinal section of a group pipe.
[Drawing 3]the heat exchange used for the 1st example at adsorption equation heat pump — public funds — it is a graph which shows the adsorption isotherm of the fixed zone of a group pipe.
[Drawing 4]It is a graph which shows the temperature change to time when an adsorption test is done by the adsorption equation heat pump of the 1st example.
[Drawing 5]It is a graph which shows the temperature change to time when a desorption examination is done by the adsorption equation heat pump of the 1st example.
[Drawing 6]It is an explanatory view showing the adsorption equation heat pump of the 1st comparative example.
[Drawing 7]It is a graph which shows the temperature change to time when an adsorption test is done by the adsorption equation heat pump of the 1st comparative example.
[Drawing 8]It is a graph which shows the temperature change to time when a desorption examination is done by the adsorption equation heat pump of the 1st comparative example.
[Drawing 9]the heat exchange used for the adsorption equation heat pump of the 2nd example — public funds — it is drawing of longitudinal section of a group pipe.
[Drawing 10]It is an explanatory view showing the cooling mode of adsorption equation heat pump.
[Drawing 11]It is an explanatory view showing the temperature-up mode of adsorption equation heat pump.
[Description of Notations]
1 ... Adsorption tower,
3 ... An evaporator/condenser,
5 ... Interconnecting tube,
10 ... Adsorption equation heat pump,
11, 16 ... Metal tube for heat exchange,
13 ... Feed hole,
14 ... Adsorption material,
15 ... Fixed zone,
17, 18 ... Copper pipe,
18a ... Fin

[Translation done.]

* NOTICES *

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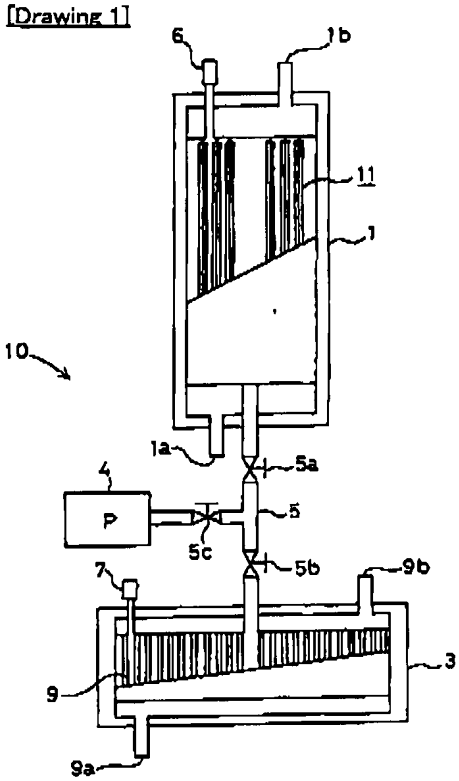
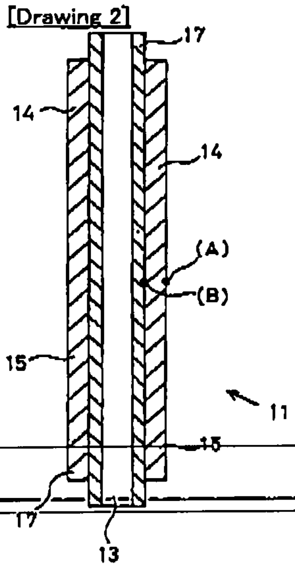
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

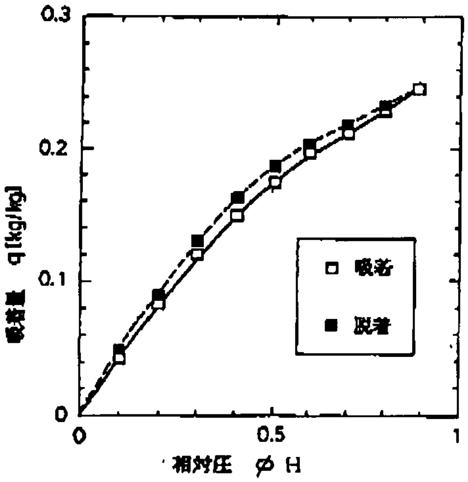
[Drawing 1]



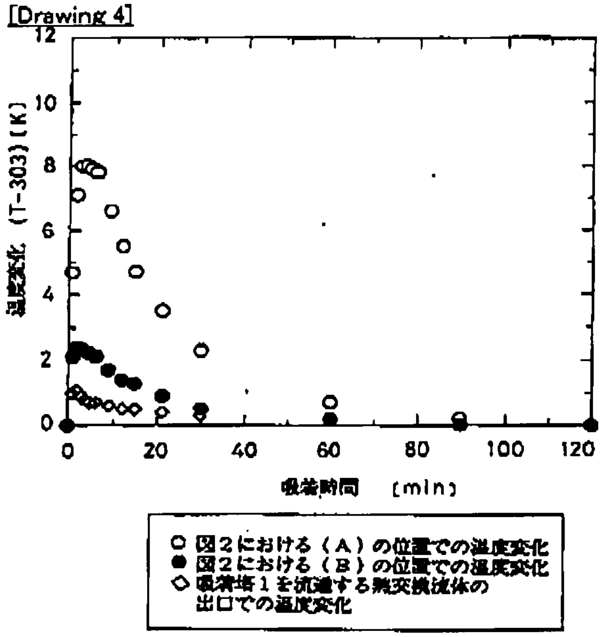
[Drawing 2]



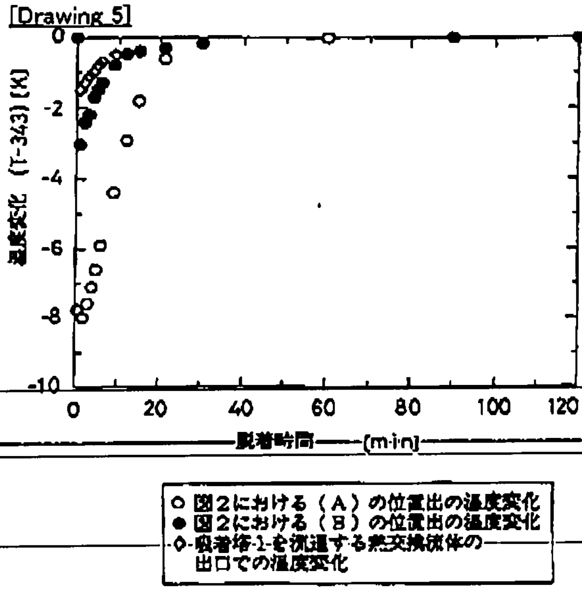
[Drawing 3]



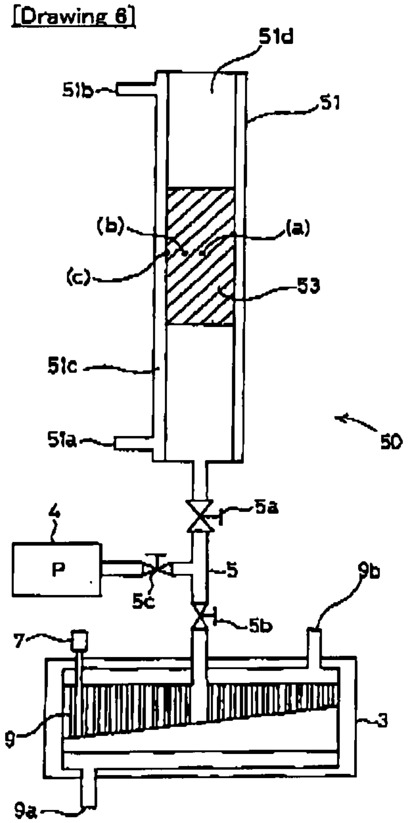
[Drawing 4]



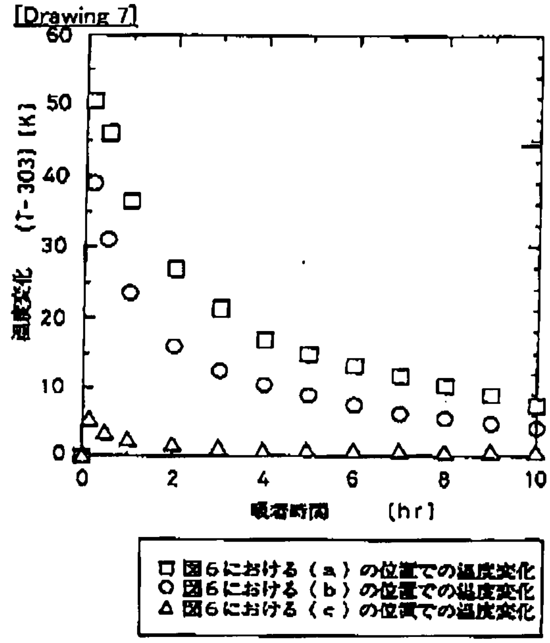
[Drawing 5]



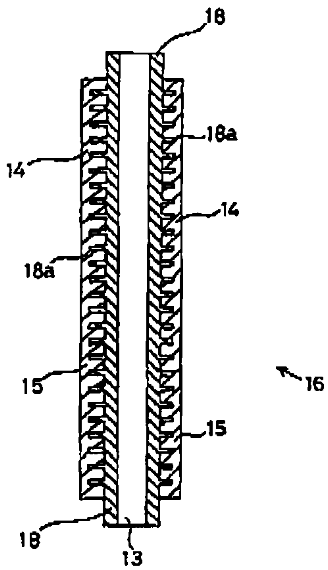
[Drawing 6]



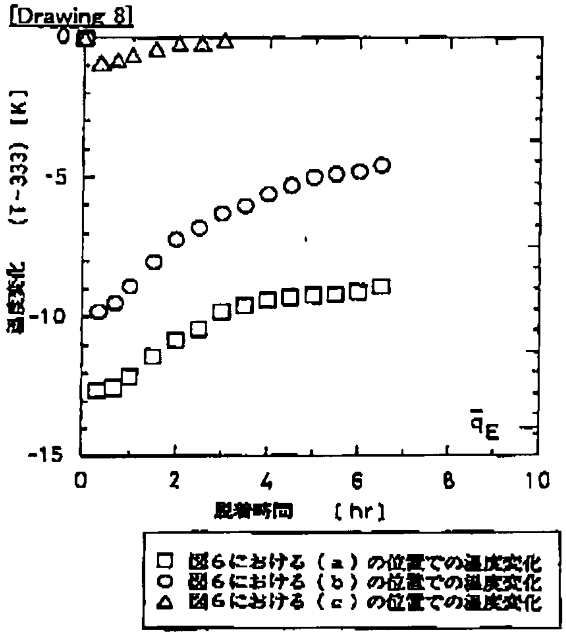
[Drawing 7]



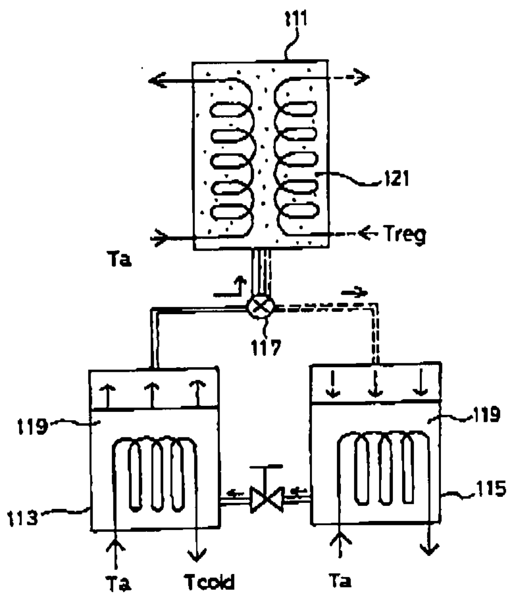
[Drawing 9]



[Drawing 8]



[Drawing 10]



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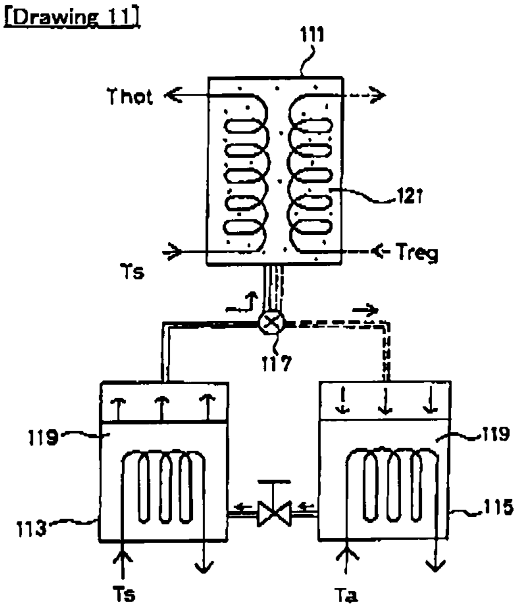
[Drawing 11]



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[Translation done.]

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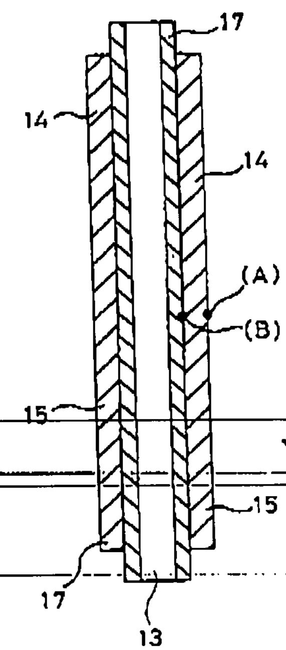
最終頁に続く

(54)【発明の名称】　熱交換用金属管及び吸着式ヒートポンプ

(57)【要約】

【目的】　吸着塔における吸着材の吸脱着が短時間で実施可能な吸着式ヒートポンプの提供。

【構成】　熱交換用金属管１１は、熱交換流体が流通可能な中心孔１３と、外周面に吸着材１４が固定された固定層１５とを有している。固定層１５は吸着材１４としてシリカゲルを４２メッシュまで粉砕し、酢酸ビニル系バインダを混合して銅管１７の外周面に接着し１１０℃で６時間焼成することにより成形した。吸着式ヒートポンプの吸着塔に、作動流体としての水が流通可能な空間を残すようにして複数の熱交換用金属管１１を配置することにより、吸着材が吸脱着して温度変化が生じた後熱交換が効率的に行われ、更に作動流体が吸着塔内を均一に拡散し吸着量分布に大きな偏りを生じないという効果があった。これにより、従来の吸着式ヒートポンプに比べ、１サイクルに要する時間が短縮化された。



【特許請求の範囲】

【請求項1】　熱交換流体が流通可能な中心孔と、外周面に吸着材が層状に固定された固定層とを有することを特徴とする熱交換用金属管。

【請求項2】　作動流体を吸着することにより発熱し、吸熱することにより前記作動流体を脱着する吸着材を有する吸着塔と、

前記吸着塔に連結された蒸発器と、

前記吸着塔に連結された凝縮器とを備えた吸着式ヒートポンプにおいて、

前記吸着塔には、前記作動流体が流通可能な空間を残すようにして複数の請求項1記載の熱交換用金属管が配置されたことを特徴とする吸着式ヒートポンプ。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は熱交換効率の優れた熱交換用金属管と、その熱交換用金属管を利用した吸着式ヒートポンプに関する。

【0002】

【従来の技術】近年、各種工業プロセスから様々な温度レベルの排熱が大量に排出されている。なかでも１００℃以下の有効熱エネルギーは総排熱の３／４以上を占めるにも関わらず、その大半は利用されないまま廃棄されているのが現状である。このような低温排熱を質的レベルの高い熱エネルギーに変換する技術の一つとして吸脱着に伴う発熱・吸熱を利用する吸着式ヒートポンプが知られている。吸着式ヒートポンプは以下に掲げる特徴を備えているため、有用視されている。

①熱源温度や排出量の低下による能力低下が小さい。

②１００℃以下の低温熱源でも操作が可能である。

③蓄熱・冷熱効果がある。

④使用する吸着材は安全性が高く、腐食性がない。

⑤原理的には、機械的動力を必要としない。

【０００３】従来の吸着式ヒートポンプは、作動流体と吸着材を適宜選択し、蒸発器、凝縮器及び吸着材を有する吸着塔を備えたものが知られていた。この吸着材としては粉末又は粒状が多用されていたため、吸着塔は吸着材を通気性良く充填するという、いわゆる充填方式により形成するのが主流であった。

【０００４】吸着式ヒートポンプの原理を図１０及び図１１により説明する。冷却モードでは図１０の吸着式ヒートポンプ１１０を、まずバルブ１１７により蒸発器１１３と吸着塔１１１とを連結して蒸発器１１３より作動流体１１９を蒸発させ、吸着塔１１１内の吸着材１２１に所定の吸着量に達するまで吸着させる。このとき、作動流体１１９の蒸発により蒸発器１１３の温度が低下し、蒸発器１１３内の熱交換器を通して温度T_aの水を温度T_{cold}まで低下させることができる。一方、吸着塔１１１内の熱交換器は温度T_aの水を流すことにより吸着材１２１を冷却する。作動流体１１９の吸着量が所定

量に達したらバルブ１１７を切換え、吸着塔１１１と凝縮器１１５を接続し、吸着塔１１１に熱源温度T_{reg}の温水を流して昇温し、作動流体１１９を吸着材１２１から脱着して凝縮器１１５で凝縮させる。このとき凝縮器１１５には温度T_aの水を流す。脱着が終了した段階で１サイクルが完了し、再び吸着過程を行う。

【０００５】昇温モードでは図１１に示したように、まずバルブ１１７により蒸発器１１３と吸着塔１１１を連結し、両方に熱源温度T_sの温水を流しながら吸着材１２１に作動流体１１９を吸着させる。このとき、吸着材１２１の吸着熱により吸着塔１１１の温度が上昇し、吸着塔１１１内を流れる熱源温度T_sをT_{hot}まで昇温させることができる。作動流体１１９の吸着量が所定量に達したらバルブ１１７を切換え、吸着塔１１１と凝縮器１１５を接続し、吸着塔１１１に熱源温度T_{reg}の温水を流して昇温し、作動流体１１９を吸着材１２１から脱着して凝縮器１１５で凝縮させる。このとき凝縮器１１５に温度T_aの水を流す。脱着が終了した段階で１サイクルが完了し、再び吸着過程を行う。

【０００６】

【発明が解決しようとする課題】しかしながら従来の吸着式ヒートポンプでは、冷却モード及び昇温モードのいずれにおいても１サイクルに要する時間が長いことが問題となっていた。この主な原因は、吸着塔における吸着材と熱交換流体との熱交換が迅速に行われなかったことにあった。即ち、従来の吸着式ヒートポンプの吸着塔は、粉末あるいは粒状の吸着材を充填することにより形成されていたため、圧力損失が大きく、作動流体の吸着塔内における拡散が不均一になり、吸着塔内の吸着量分布の偏りが起こりやすかった。ところがこの吸着塔では、熱交換流体と距離を隔てた場所に位置する吸着材は、熱交換流体との熱交換はほとんど行われず、近接した他の吸着材によって熱伝導を受けるかあるいは吸着塔を流通する作動流体によって熱伝導を受けるのみであるため、前述の吸着量分布の偏りが生じると吸着塔内を所定の温度に制御するのに長時間を要した。

【０００７】吸着の際に吸着材の温度が設定した温度以上になると、発熱反応の平衡は生成系よりも反応系に片寄るため吸着材の吸着能力が減少し、結果的に吸着速度が遅くなる。一方、脱着の際には吸着材に吸着熱相当の熱を効率的に付与しないと、吸熱反応の平衡は反応系に片寄り脱着速度が低下してしまう。このような理由から、従来の充填方式による吸着塔を有する吸着式ヒートポンプでは、吸着時間と脱着時間が１サイクルに要する時間の律速となっていた。

【０００８】以上の課題を解消するため本発明は、吸着塔における吸着材の吸脱着が短時間で実施可能な吸着式ヒートポンプの提供を目的とする。

【０００９】

【課題を解決するための手段及び作用】上記の課題を解

決するため、第１発明の熱交換用金属管は、熱交換流体が流通可能な中心孔と、外周面に吸着材が層状に固定された固定層とを有することを要旨とする。

【００１０】第２発明の吸着式ヒートポンプは、作動流体を吸着することにより発熱し、吸熱することにより前記作動流体を脱着する吸着材を有する吸着塔と、前記吸着塔に連結された蒸発器と、前記吸着塔に連結された凝縮器とを備えた吸着式ヒートポンプにおいて、前記吸着塔には、前記作動流体が流通可能な空間を残すようにして第１発明の熱交換用金属管が配置されたことを要旨とする。

【００１１】以下、本発明の構成及び作用について詳述する。まず第１発明の熱交換用金属管について説明する。使用する金属管の種類は特に限定しないが、例えば、銅、ステンレス、アルミ等及びこれらを含んだ合金などが好ましく、特に銅が好ましい。また金属管は熱交換流体が流通可能な中心孔を有する構造であること以外特に限定しないが、例えばフィン付管構造の場合、熱交換効率の点から特に好ましい。

【００１２】吸着材としては特に限定しないが、例えばシリカゲル、活性アルミナ、活性炭、ゼオライト、モレキュラーシービングカーボンなどが好ましく、特にシリカゲル、活性炭が好ましい。また、吸着材の物性については、粒径２ｍｍ以下、細孔容積０．３ｍｌ／ｇ以上、比表面積６００m^2／ｇ以上であることが好ましい。

【００１３】吸着材を金属管外周面に固定したときの固定層の厚さは、金属の外周面に接触する部分と固定層の外周面との間に極度の温度分布を生じさせないために、１～６ｍｍであることが好ましく、２～３ｍｍであることが特に好ましい。厚さが下限以下になると固定層を成形する上での強度に問題があり、上限以上になると熱交換流体との熱交換の効率の低下、固定層内での吸着量の分布の偏りが極度に大きくなること等が危惧される。

【００１４】固定層の成形方法は特に限定しないが、吸着材に接着用の合成樹脂を含有させたものを金属管外周面に塗布した後焼成により層を成形する方法などが一般的である。なお熱交換流体については、通常用いられるものであれば液体、気体を問わずに使用してよいが、液体としては水、オイルなどが好ましく、気体としては空気、窒素、炭酸ガスなどが好ましい。

【００１５】第１発明の熱交換用金属管を使用すれば、金属管の熱伝導性が高いこと、固定層が金属管の中心孔を流れる熱交換流体と充分速い速度で熱交換できることから、金属管の外周面に固定層として形成された吸着材を熱交換流体により迅速に温度制御することが可能となる。

【００１６】続いて第２発明の吸着式ヒートポンプについて説明する。第２発明の吸着式ヒートポンプに使用される作動流体は、通常の吸着式ヒートポンプに使用可能なものであればよく、例えば水、低級アルコール、芳香族炭化水素、アンモニア、アセトンなどが挙げられる。特に蒸発潜熱、蒸気圧、毒性などを考慮すると、水、エタノールが好ましい。

【００１７】吸着塔は、作動流体が流通可能な空間を残すようにして複数の第１発明の熱交換用金属管が配置されているが、ここで作動流体が流通可能な空間とは、蒸発器において気化した作動流体又は吸着材から脱着した作動流体が、吸着塔の内部全体を均一に拡散できるのに充分な空間を意味する。この空間の存在により、吸着塔内での軸方向の吸着量分布の偏りが減少し、吸着材の吸着及び脱着時間を短縮化できる。

【００１８】第２発明の吸着式ヒートポンプは、冷却モード又は昇温モードにおける吸着過程では、吸着塔内の吸着材が作動流体を吸着することにより発生する吸着熱を、第１発明の熱交換用金属管を使用することによりきわめて迅速に吸着材から除去することができる。その結果、吸着速度を低下させることなく所定の吸着量に速やかに達することができる。また脱着過程では熱交換流体から吸着熱に相当する熱量を迅速に吸着材に付与することができるため、吸着材を速やかに再生することができる。

【００１９】

【実施例】本発明の好適な実施例について以下に説明する。図１に第１実施例の吸着式ヒートポンプ１０を示す。本実施例の構成は、吸着塔１、蒸発器／凝縮器３及び連結管５からなっている。また吸着系には吸着材としてシリカゲルを、作動流体として水を使用し、熱交換流体には所定温度に設定した水を使用した。

【００２０】本実施例では蒸発器と凝縮器を別々の構成にせず、同一の機器を使用目的に応じて蒸発器、あるいは凝縮器に使い分けることとし、この機器を蒸発器／凝縮器３とした。この蒸発器／凝縮器３は、過剰圧力により開弁する安全弁７を有する断熱密閉容器からなる。また、内部に存在する作動流体としての水と熱交換を行うため、熱交換パイプ９が配設されている。熱交換パイプ９は入口９ａ及び出口９ｂを有し、熱交換流体として水を流通又は循環ポンプ等により循環させることができ、更に入口温度を所定の温度に設定することができる。なお、蒸発器／凝縮器３の有効蒸発面積は０．０３１４ｍ2である。

【００２１】吸着塔１は、過剰圧力により開弁する安全弁６を有し、内径１３３ｍｍ、外径１６５．２ｍｍの断熱密閉容器からなり、内部には複数の熱交換用金属管１１（後述）が、作動流体としての水が流通可能な空間を残すようにして配置されている。この吸着塔１は１５本の熱交換用金属管１１からなり、熱交換流体の入口１ａから熱交換用金属管１１の中心孔１３を経て出口１ｂへと水を流通させることにより図２に示す吸着材１４の温度を調節できるようになっている。この熱交換流体としての水は入口温度を所定の温度に設定することができ

る。ここで熱交換用金属管11について詳述する。

【0022】熱交換用金属管11は図2に示すように、熱交換流体が流通可能な中心孔13と、外周面に吸着材14が固定された固定層15とを有している。本実施例では、内径4mm、外径6mmの銅管17を用いて、吸着材14としてシリカゲルC（富士デヴィソン化学（株）製、比表面積721×10^3m^2／kg、細孔容積0．42×$10^{-3}m^3$／kg）を42メッシュ（粒径355μm以下）まで粉砕し、酢酸ビニル系バインダを混合して前記銅管17の外周面に接着し110℃において6時間焼成することにより、厚さ2mm、長さ400mmの固定層15を形成した。この固定層15の比表面積は200×10^3m^2／kg、細孔容積は0．12×$10^{-3}m^3$／kg（いずれもB．E．T法により算出）であった。また、この固定層15の吸着等温線（温度30℃で測定）を図3に示す。

【0023】連結管5は、作動流体である水が蒸発器／凝縮器3の内部と吸着塔1の内部とを往来できるように、両者を連結している。連結管5は蒸発器／凝縮器3と吸着塔1を連結する経路の他、真空ポンプ4に通じる経路を有するため三叉路を形成し、それぞれを独立して密閉することを可能にする3つのバルブ5a，5b，5cを有している。

【0024】以上の構成からなる本実施例の吸着式ヒートポンプ10を、冷却モードで使用した場合を例にとり、以下にその作用、効果について詳述する。本実施例の吸着式ヒートポンプ10には、熱交換用金属管11の固定層15表面温度（図2における（A）の位置）、銅管17の表面温度（図2における（B）の位置）、蒸発器／凝縮器3内部の作動流体の温度、及び吸着塔1及び蒸発器／凝縮器3を流通する熱交換流体の出入口温度を、それぞれ経時の測定が可能となるように該当位置に測定機器を備え付けた。

<吸着試験>本実施例の吸着式ヒートポンプ10を作動する前に以下の前処理を行った。まず熱交換流体の入口1aから温度80℃の水を熱交換用金属管11の中心孔13に流通しつつバルブ5bを閉じバルブ5a，5cを開くことにより、吸着塔1の内部を真空脱気した。次にバルブ5aを閉じバルブ5b，5cを開くことにより蒸発器／凝縮器3の脱気を行い、作動流体である水の不純成分を除去し、バルブ5b，5cを閉じた。

【0025】次いで、吸着塔1の熱交換流体として温度30℃の水を、蒸発器／凝縮器3の熱交換流体として温度10℃の水をそれぞれ1．6×$10^{-4}m^3$／s、1．4×$10^{-4}m^3$／sの水量で流通した。熱交換用金属管11の固定層15表面温度、銅管17の表面温度、及び蒸発器／凝縮器3内部の作動流体の温度が所定温度に達したことを確認後、バルブ5a，5bを開き吸着塔1内部に作動流体として水の蒸気を導入し、吸着を開始した。吸着開始後の経過時間をX軸、温度の変化量をY軸にとり、図2における（A）の位置での温度変化（○で表示）、図2における（B）の位置での温度変化（●で表示）、吸着塔1を流通する熱交換流体の出口での温度変化（◇で表示）をそれぞれ図4に示した。

<脱着試験>吸着試験に続き、吸着塔1の熱交換流体として温度70℃の水を、蒸発器／凝縮器3の熱交換流体として温度30℃の水を流通して脱着試験を行った。脱着開始後の経過時間をX軸、温度の変化量をY軸にとり、図2における（A）の位置での温度変化（○で表示）、図2における（B）の位置での温度変化（●で表示）、吸着塔1を流通する熱交換流体の出口での温度変化（◇で表示）をそれぞれ図5に示した。

【0026】次に、第1比較例として第1実施例の吸着式ヒートポンプ10の吸着塔1を、充填式吸着塔に置換したタイプの吸着式ヒートポンプ50（図6）を用いて、吸着、脱着試験を行った。この吸着塔51は2重管構造になっており、熱交換流体の入口51aから2重管の外管51cを経て出口51bへと水を流通させることにより吸着材53の温度を調節できるようになっている。吸着塔51は内径54mm×長さ200mmの円柱状で、吸着材53としてシリカゲルA（富士デヴィソン化学（株）製）を吸着塔51の内管51dにランダム充填した。シリカゲルAの物性は、比表面積が721×$10^{-3}m^2$／kg、細孔容積が0．43×10^3m^3／kgである。

【0027】この吸着式ヒートポンプ50による吸着試験では吸着塔51を流通する水温を30℃、蒸発器／凝縮器3を流通する水温を25℃に設定し、また脱着試験では吸着塔51を流通する水温を60℃、蒸発器／凝縮器3を流通する水温を30℃に設定した。なお吸着試験は第1実施例と同様の前処理を行った後実施した。図7及び図8に、吸着試験及び脱着試験における吸脱着開始後の経過時間をX軸、吸着材の温度の変化量をY軸にとり、図6における（a）の位置での温度変化を□、図6における（b）の位置での温度変化を○、図6における（c）の位置での温度変化を△で表示した。

【0028】第1実施例と比較例との吸着及び脱着試験の結果を表1にまとめた。

【0029】

【表1】

	第1実施例	第1比較例
<吸着試験>		
吸着に要する時間（h）	1．5	＞10
吸着材の最大温度変化（K）	8	50
吸着材の最大温度分布幅（K）	6	45
<脱着試験>		
脱着に要する時間（h）	0．5	＞ 6
吸着材の最大温度変化（K）	8	13
吸着材の最大温度分布幅（K）	5	12
1サイクルに要する時間（h）	2．0	＞16

【0030】吸着材の最大温度変化は、第1実施例では吸脱着初期の固定層表面（図2（A））において、第1比較例では吸脱着初期に中央部軸方向に位置する吸着材（図6（a））において、それぞれ記録した。この数値は、吸着材が作動流体を吸脱着して温度変化が生じた後、熱交換が効率的に行われたかどうかの指標となる。

【0031】吸着材の温度分布幅は、第1実施例では固定層表面（図2（A））と金属管表面（図2（B））との間に生じた温度差であり、第1比較例では中央部軸方向に位置する吸着材（図6（a））と吸着塔熱交換流体近傍に位置する吸着材（図6（c））との間に生じた温度差である。最大温度分布幅はいずれも吸脱着初期において記録した。この数値は、吸着材が作動流体を吸脱着して温度変化が生じた後熱交換が効率的に行われているかどうか、あるいは作動流体が吸着塔内を均一に拡散し吸着量分布に偏りが生じているかどうか、の指標となる。

【0032】表1から明らかなように、第1実施例の吸着式ヒートポンプは第1比較例に比べて、吸着材の最大温度変化及び吸着材の最大温度分布幅が小さくなっている。この結果は、吸着材が作動流体を吸脱着して温度変化が生じた後熱交換が効率的に行われたこと、更に作動流体が吸着塔内を均一に拡散し吸着量分布に大きな偏りが生じていないことを示している。

【0033】また、第1実施例では第1比較例に比べて、吸着及び脱着時間が極めて短縮化され、1サイクルを短時間で行うことができるようになった。次に第2実施例の吸着式ヒートポンプについて説明する。第2実施例の吸着式ヒートポンプ自体は特に図示しないが、第1実施例の吸着式ヒートポンプ10に使用した熱交換用金属管11に代えて、図9に図示した熱交換用金属管16を使用した以外は、第1実施例の吸着式ヒートポンプ10と同様の構成である。熱交換用金属管16は、外表面にフィン18aを装着もしくは一体形成された銅管18を用いたこと以外は、熱交換用金属管11と同様にして製作した。

【0034】第2実施例の吸着式ヒートポンプではフィン18aの存在により、熱交換用金属管16の熱伝導性がより向上し、固定層15と中心孔13を流れる熱交換流体との熱交換効率が第1実施例に比べて一層向上した。このため、第2実施例の吸着式ヒートポンプでは第1実施例の吸着式ヒートポンプ10と同様の効果を有することはいうまでもないが、更に、吸着及び脱着時間がより一層短縮化されたことに伴い、1サイクルをより一層短時間で行うことができるようになった。

【0035】以上詳述したように、第2発明の吸着式ヒートポンプは吸着塔に作動流体が流通可能な空間を残して複数の第1発明の熱交換用金属管を配置したことにより、1サイクルに要する時間が極めて短くなった。なお、本発明は上記実施例になんら限定されるものではなく、本発明の趣旨を逸脱しない範囲において種々の態様で実施できることはいうまでもない。例えば第1実施例では冷却モードについて説明をしたが、昇温モードについても全く同様の構成及び作用をもって、1サイクルに要する時間が極めて短くなるという効果を有する。

【0036】

【発明の効果】以上詳述したように、第1発明の熱交換用金属管によれば、金属管の熱伝導性が高いこと、固定層が金属管の中心孔を流れる熱交換流体と充分速い速度で熱交換できることから、金属管の外周面に固定層として形成された吸着材を熱交換流体により迅速に温度制御することが可能となる。

【００３７】第２発明の吸着式ヒートポンプは吸着塔に作動流体が流通可能な空間を残して複数の第１発明の熱交換用金属管を配置したことにより、吸着塔における吸着材の吸脱着が短時間で実施可能となった。この結果冷却モード及び昇温モードにおいて、１サイクルに要する時間が極めて短くなった。

【図面の簡単な説明】

【図１】　第１実施例の吸着式ヒートポンプを示す説明図である。

【図２】　第１実施例の吸着式ヒートポンプに使用した熱交換用金属管の縦断面図である。

【図３】　第１実施例に吸着式ヒートポンプに使用した熱交換用金属管の固定層の吸着等温線を示すグラフである。

【図４】　第１実施例の吸着式ヒートポンプにより吸着試験を行ったときの時間に対する温度変化を示すグラフである。

【図５】　第１実施例の吸着式ヒートポンプにより脱着試験を行ったときの時間に対する温度変化を示すグラフである。

【図６】　第１比較例の吸着式ヒートポンプを示す説明図である。

【図７】　第１比較例の吸着式ヒートポンプにより吸着

試験を行ったときの時間に対する温度変化を示すグラフである。

【図８】　第１比較例の吸着式ヒートポンプにより脱着試験を行ったときの時間に対する温度変化を示すグラフである。

【図９】　第２実施例の吸着式ヒートポンプに使用した熱交換用金属管の縦断面図である。

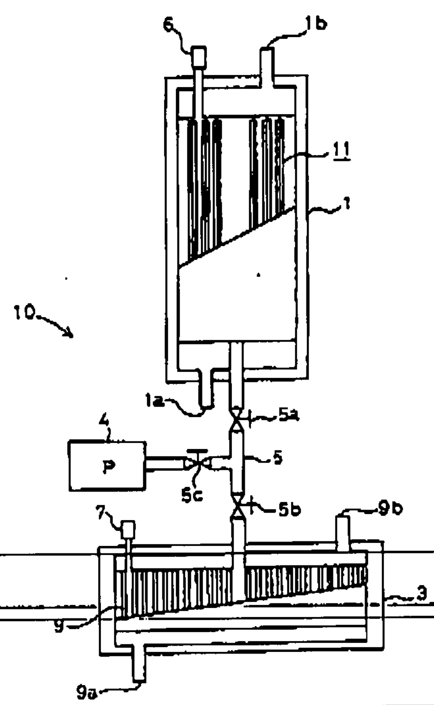
【図１０】　吸着式ヒートポンプの冷却モードを示す説明図である。

【図１１】　吸着式ヒートポンプの昇温モードを示す説明図である。

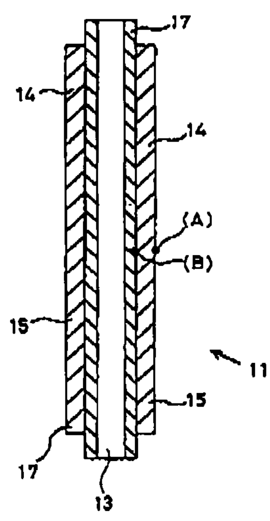
【符号の説明】

１・・・吸着塔、
３・・・蒸発器／凝縮器、
５・・・連結管、
１０・・・吸着式ヒートポンプ、
１１，１６・・・熱交換用金属管、
１３・・・中心孔、
１４・・・吸着材、
１５・・・固定層、
１７，１８・・・銅管、
１８a・・・フィン

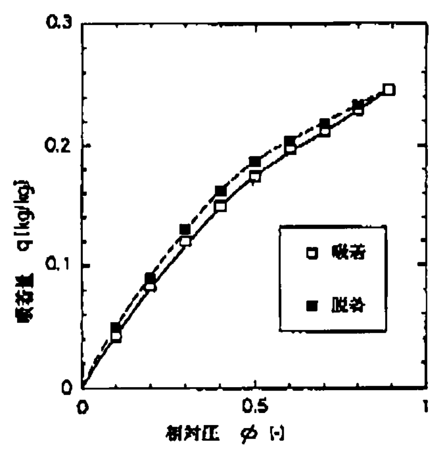
【図１】



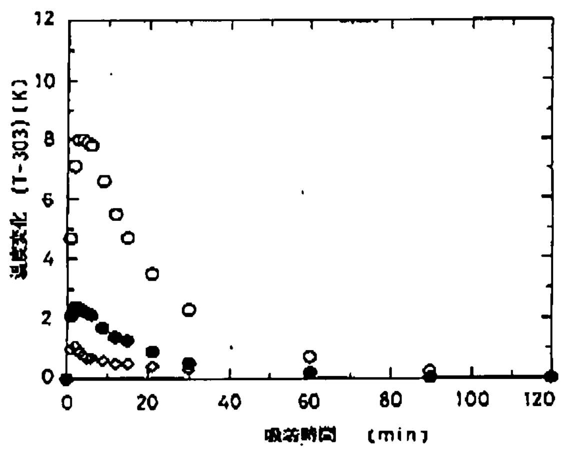
【図２】



【図３】

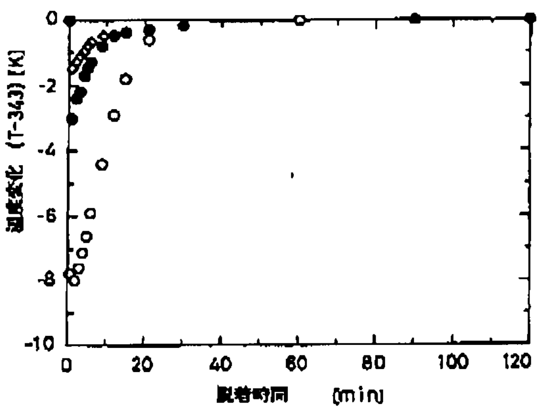


【図4】



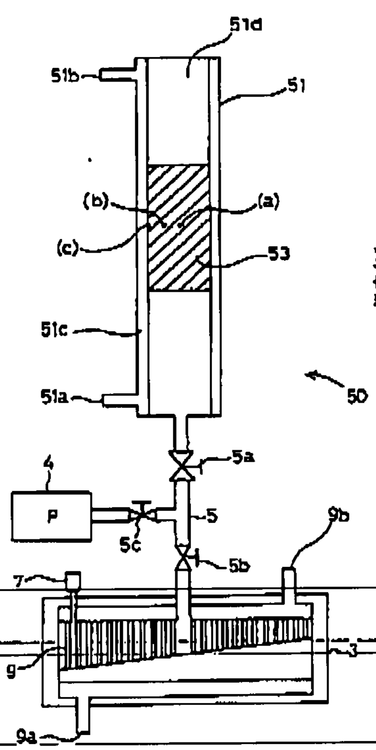
○ 図2における(A)の位置での温度変化
● 図2における(B)の位置での温度変化
◇ 吸着塔1を流通する熱交換流体の出口での温度変化

【図5】

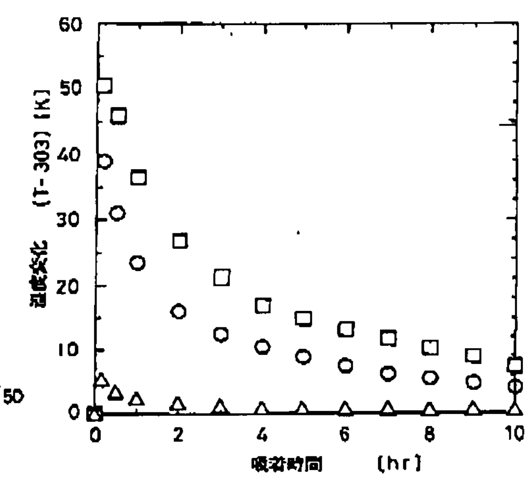


○ 図2における(A)の位置出の温度変化
● 図2における(B)の位置出の温度変化
◇ 吸着塔1を流通する熱交換流体の出口での温度変化

【図6】

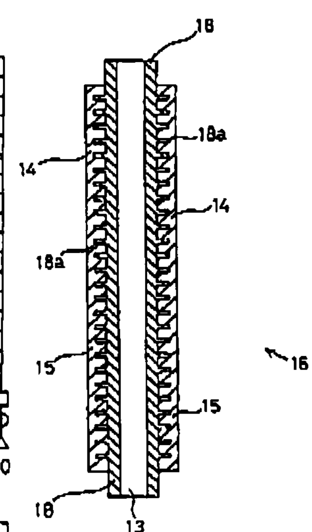


【図7】

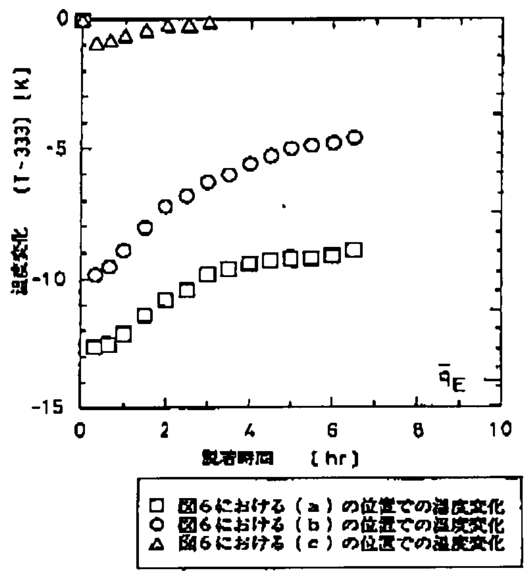


□ 図6における(a)の位置での温度変化
○ 図6における(b)の位置での温度変化
△ 図6における(c)の位置での温度変化

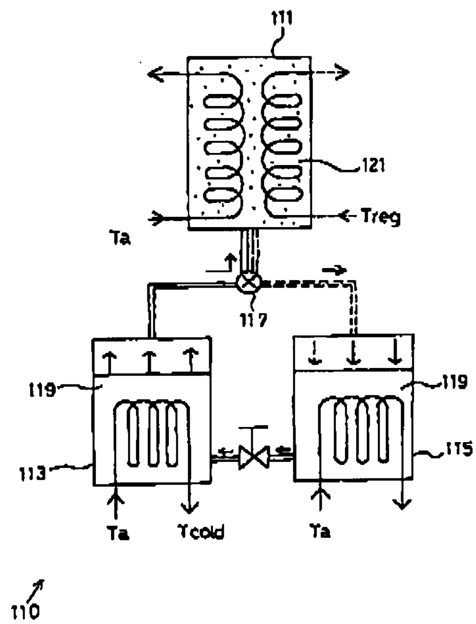
【図9】



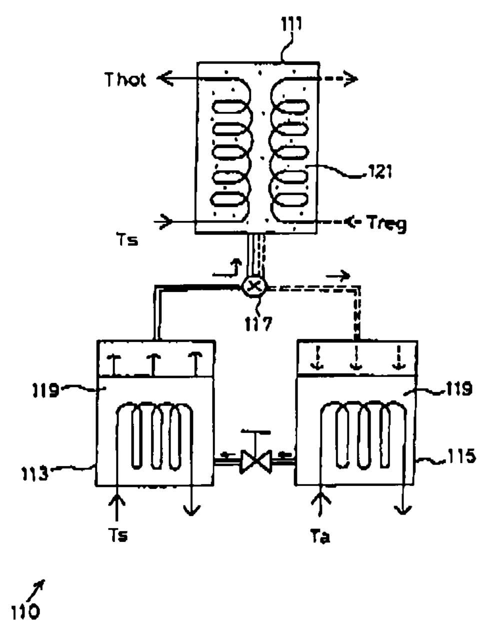
【図8】


0
-5
-10
-15
温度変化 (T-333) [K]
0
2
4
6
8
10
脱着時間 [hr]
$\bar{q}_E$
□ 図6における(a)の位置での温度変化
○ 図6における(b)の位置での温度変化
△ 図6における(c)の位置での温度変化

【図10】


111
121
Treg
Ta
117
119
119
113
115
Ta
Tcold
Ta
110

【図11】


111
Thot
121
Ts
Treg
117
119
119
113
115
Ts
Ta
110

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